Investigation on the hydrodynamics of the catamaran hull of a floating tidal power generation device

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Summary: Tidal energy as an alternative clean and renewable energy source has recently aroused much interest among both academia and industry. Floating tidal power generation devices are also under development worldwide. In this paper, hydrodynamics of the catamaran hull of a floating tidal power generation device is investigated using a CFD solver. As an initial step, the tidal turbine is not considered. Motion and force responses of the floating platform subject to regular waves are presented and analysed.

Introduction

Over the last several decades, energy crisis, together with the public concern about environmental pollution caused by traditional fossil energy sources such as coal and oil, has motivated more and more researchers and enterprises to develop clean and renewable energy sources as alternatives. Among them, tidal energy has gradually aroused interest in many countries mostly thanks to its higher predictability than other renewable energy sources like wind and solar energy [1]. Previously, most of tidal energy devices were designed to be installed on fixed structures sitting on the seabed. Nowadays some floating structures are under development as they are comparatively cheap to construct and install as well as easy to maintain [2, 3]. In that case, the floating structure might affect the position of the tidal turbine thus play a significant role in the performance of power generation. As a result, study on the interaction between the floating structure and the tidal turbine has recently become a hot topic.

In this paper, hydrodynamics of the catamaran hull of a floating tidal power generation device is investigated using a CFD solver based on open source CFD toolbox OpenFOAM [4]. As an initial step, only the supporting hull is considered and the tidal turbine is temporarily not attached. Numerical results such as motion and force responses are presented and analysed for the floating catamaran hull subject to the regular waves.

Methods

The present solver [5] used in this paper is developed in OpenFOAM, where the two-phase incompressible RANS equations are solved by Finite Volume Method (FVM), the surface interface is captured by a VOF method with bounded compression technique, and the pressure-velocity coupling is handled by the PIMPLE algorithm which combines the well-known PISO and SIMPLE algorithms.

The solver is integrated with a numerical wave tank module for wave generation and damping, as well as a body motion system including a 6DoF motion solver and a mooring system analysis module to deal with the complex motion responses. All of these newly added modules make the existing solver ideal for simulating hydrodynamic problems for ships and floating structures in the naval architecture and ocean engineering industry.

Computational Model

The tidal turbine is supported by a catamaran hull for the floating tidal power generation device [6]. The whole structure is comprised of two identical demihulls separated by a given distance as shown below in Fig. 1. The fore and aft parts of the hull are symmetric. The structure is moored by four lines for position keeping as shown in Fig. 2. The elastic coefficient for all lines is selected as a constant as 28.23 g/mm while pretension is set to be 15 N.

Simulation has been performed in a model scale of 13.333 under regular incident wave conditions. The wave height is 0.06 m and wave length is the same as the hull length [6]. The Stokes first order deep water wave theory is adopted for wave generation. Surge, heave and pitch are free and the mooring system also works to prevent the structure from drifting away. Since the two demihulls are identical, only half of the structure is considered.

Results

The motion responses of the platform, namely surge, heave and pitch, are illustrated in Fig. 3. Surge response is constrained by the mooring lines. Otherwise, the structure will drift away with the wave. Heave response oscillates about -0.002 m rather than 0 m due to initial imbalance between the displacement and total mass. Pitch response, on the other hand, moves between 2 and -2 degrees.

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Tension force for the mooring lines is shown in Fig. 4. It is shown that the average tension for the upstream line #2 between 9 s and 15 s is 15.34 N, which is larger than 14.45 N for the downstream line #1. This is due to the fact that the structure tends to move towards the downstream region under the influence of incident waves.

Conclusions

In this paper, the hydrodynamics of a catamaran hull for a tidal turbine is investigated in waves, using a CFD solver developed in OpenFOAM. Motion and force responses are obtained and analysed, showing the ability of this solver in simulating hydrodynamic problems for floating structures. Following steps involve taking into consideration the effects of the tidal turbine, carrying out a comprehensive study under different working conditions and comparing numerical results with experimental data available.

References:
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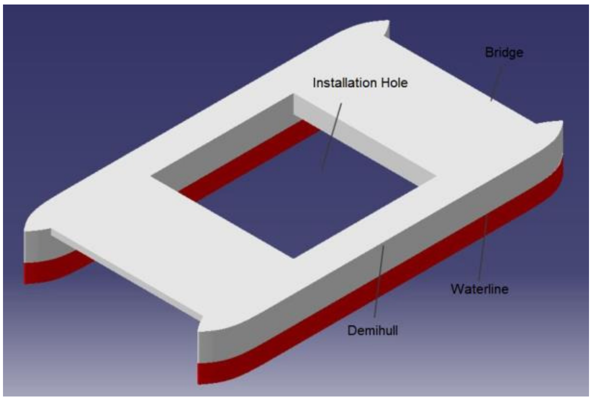

Fig. 1. Geometry of the catamaran hull

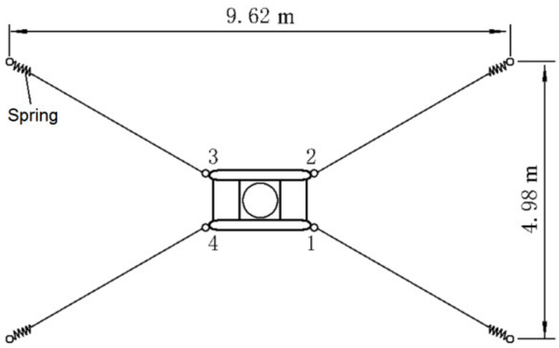

Fig. 2. Mooring system configuration

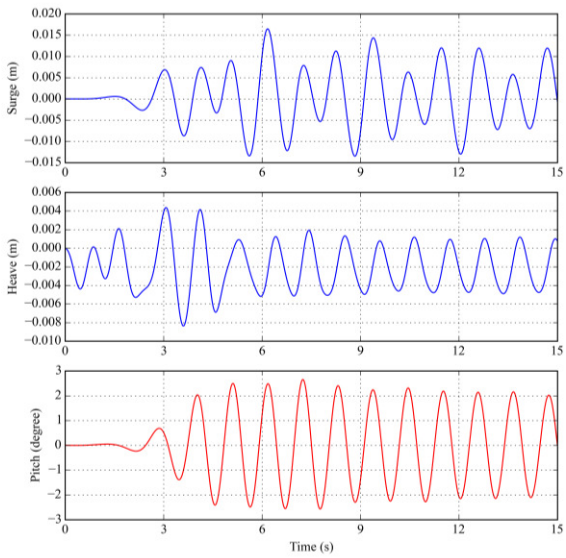

Fig. 3. Motion responses of the structure in waves

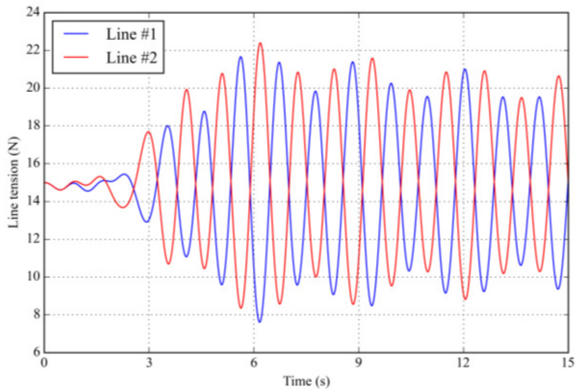

Fig. 4. Tension force for two lines

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Introduction

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About the CFD Solver

A CFD solver has been developed and is now capable of handling hydrodynamic problems of ships and offshore floating structures with mooring systems subject to waves and currents.

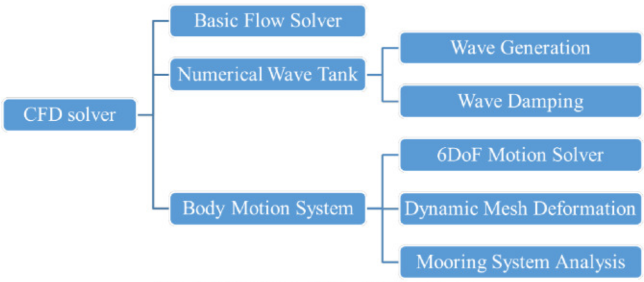
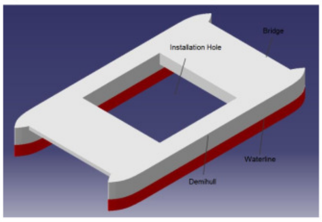


Fig. 1 Structure of the CFD solver

Computational Model

The supporting floating structure is comprised of two identical demihulls separated by a given distance. The fore and aft parts of the hull are also symmetric. Four mooring lines are used to keep the structure's position.



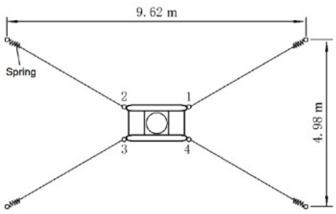
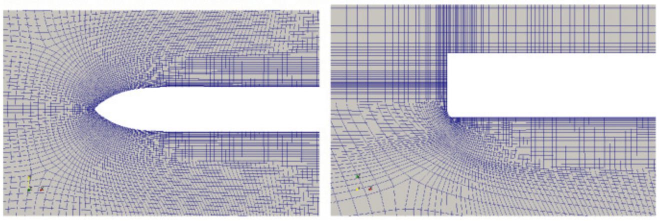


Fig. 2 Catamaran hull geometry **Fig. 3 Mooring system configuration**

Since the two demihulls are identical, only half of the structure is considered. Multi-block Cartesian mesh is generated to ensure best grid quality although OpenFOAM actually uses an unstructured means to store the mesh. The overall number of cells for this case is about 1.85 M.



(a) XOY plane **(b) XOZ plane**

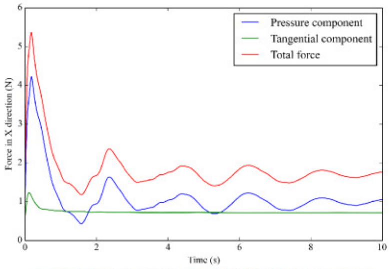
Fig. 4 Multi-block Cartesian mesh from different perspectives

Results

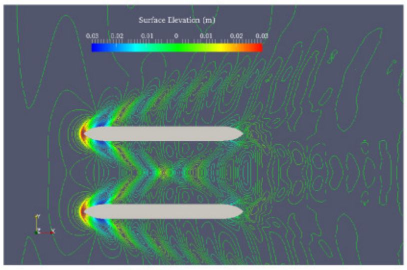
Simulation has been performed under two different working conditions: current and wave.

Current

For the current case, the speed of the current is set to 0.8 m/s while keeping the structure fixed. Fig. 5 (a) shows that the tangential component (friction force) converges more quickly than the pressure part and accounts for over 40% of the total force, indicating that viscosity plays a significant part in this kind of problems. In Fig. 5 (b), wave aroused by the bow part can be clearly seen as well as the interference between two demmihulls. However, wave pattern near the stern is not very distinct as is normally seen in others' work, which may be related to the fact that the hull is symmetry about the midship section.

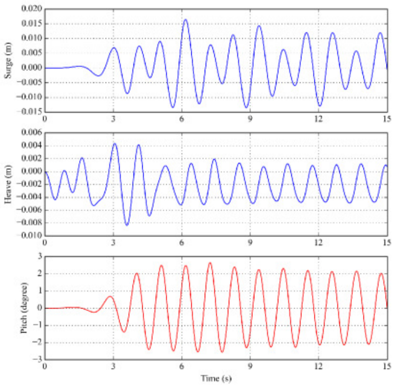


(a) Force components in X direction

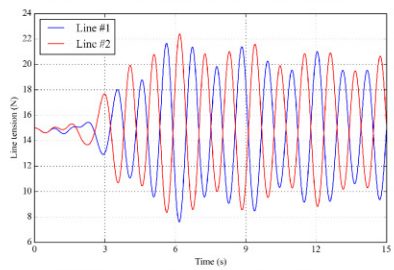


(b) Wave pattern

Fig. 5 Results from current case



(a) Motion response of structure



(b) Tension force for two lines

Fig. 6 Results from wave case

Wave

For the wave case, incident wave height is 0.06 m or 2/3 of the draught and wave length is the same as the hull length. The Stokes first order deep water wave theory is adopted for wave generation. Surge, heave and pitch are free and the mooring system also works to prevent the structure from drifting away.

Fig. 6 (a) shows the three motion responses in the XOZ plane. Surge motion is constrained by the mooring lines while pitch and heave responses oscillate round certain values. Fig. 6 (b) illustrates the tension force of the line in the downstream region (#1) is smaller than that of the upstream line (#2). This is due to the fact that the structure tends to move towards the downstream region under the influence of incident waves.

References

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